Jose Nunez, PhD

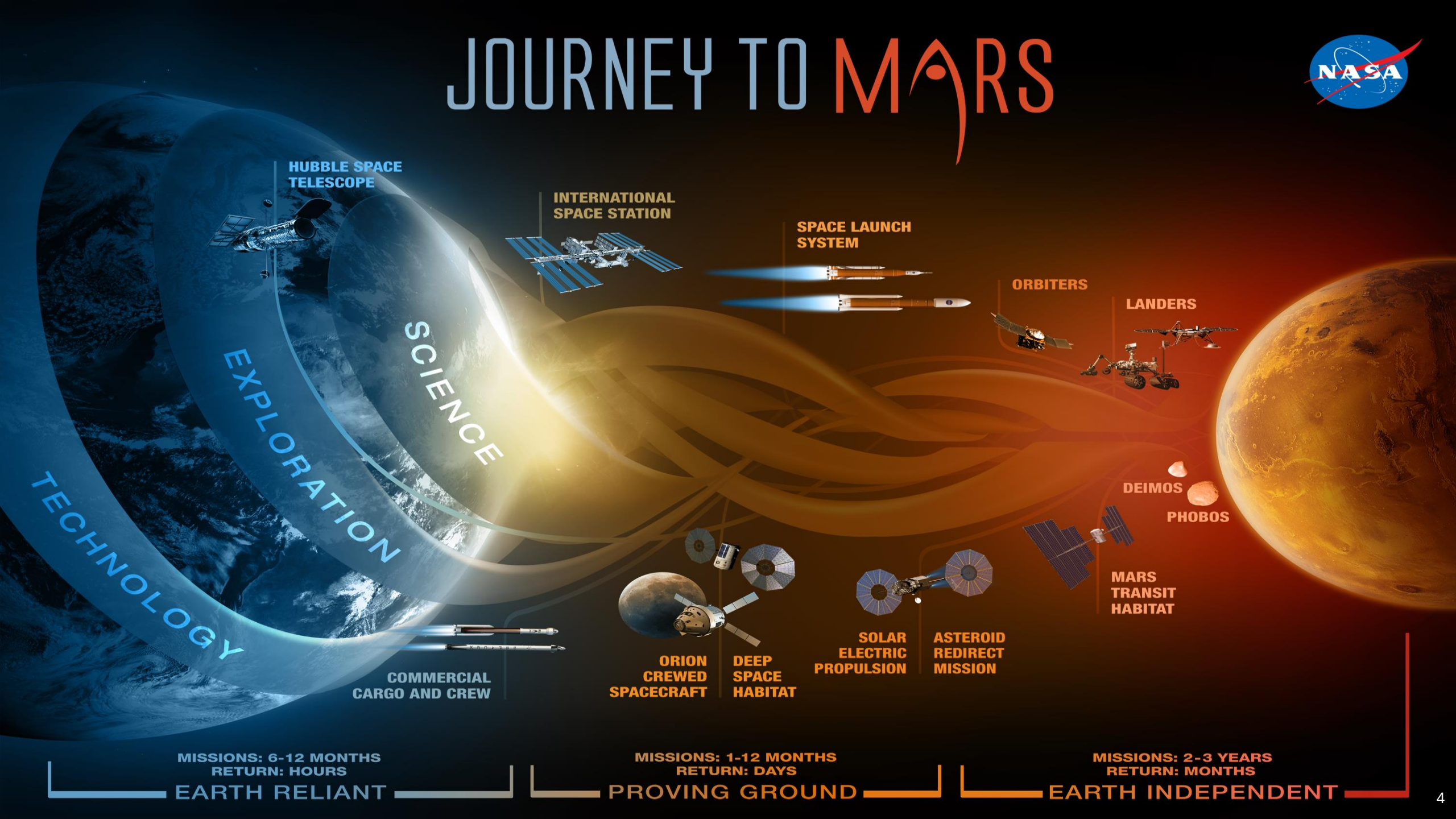
Chief, Flight Technologies Branch, UB-R2

Stanley O. Starr, UB-R3

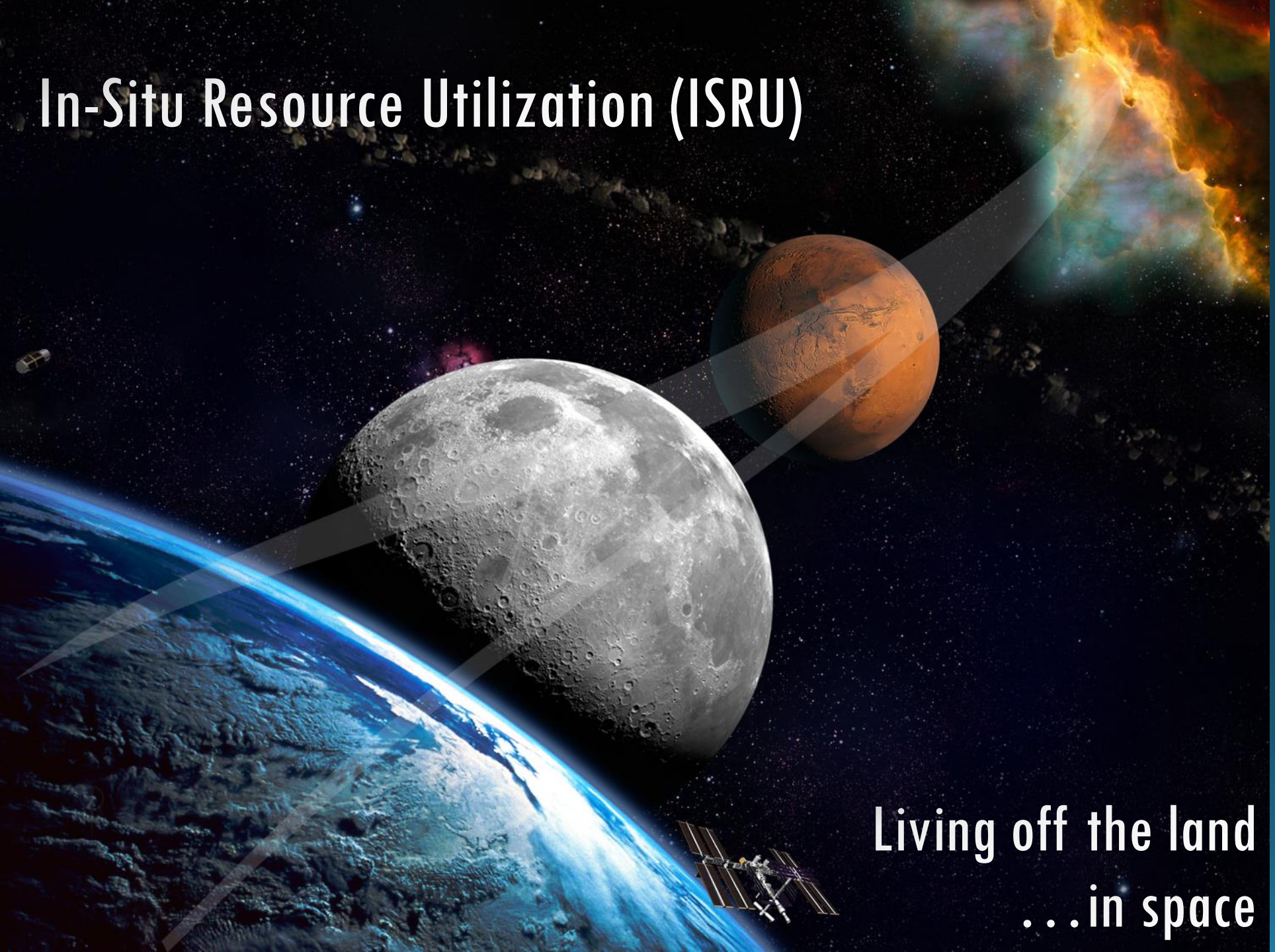
NASA Kennedy Space Center

Occupational challenges in a Planetary Work Environment

ORP 2016 XVI International Conference on Occupational Risk Prevention


JOURNEY TO MARS
NASA
HUBBLE SPACE TELESCOPE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
DEIMOS
PHOBOS
MARS TRANSIT HABITAT
COMMERCIAL CARGO AND CREW
ORION CREWED SPACECRAFT
DEEP SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

In-Situ Resource Utilization (ISRU)



Living off the land
. . . in space

Like explorers before us, we don't need to carry everything with us. In-situ resource utilization, or ISRU, is the idea of harnessing resources available at our destination, whether it is Mars, the Moon, an asteroid, or elsewhere.

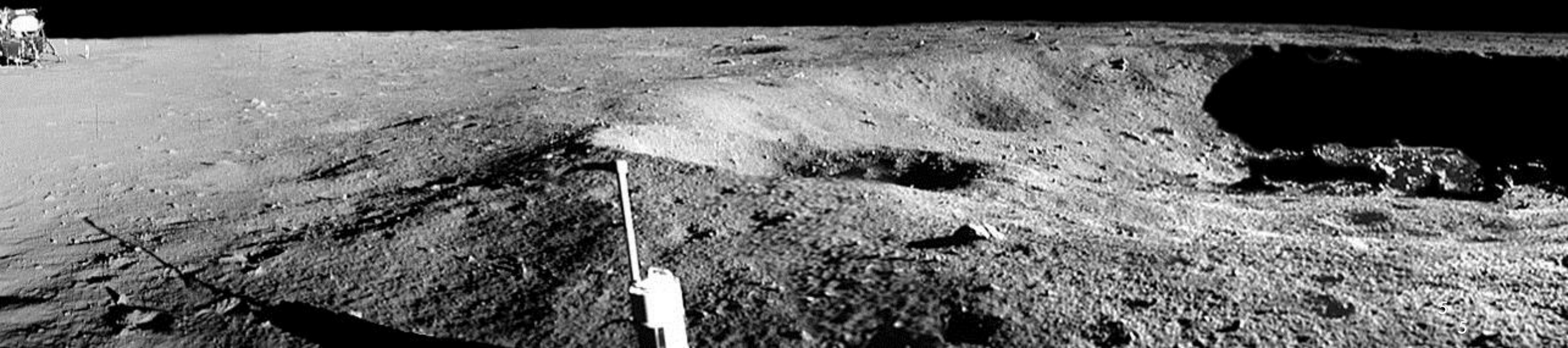
A Pioneering Heritage

- Early settlers set sail to the New World in cramped ships, and once they arrived they faced harsh weather, lack of water, among other threats to their survival.
- Pioneering Mars will have similar challenges.
- We can’t possibly bring everything we need to inhabit the Red Planet forever.
- We need to pack only the tools we need and make everything else on site.

REGOLITH AS A RESOURCE

We are exploring ways to exploit the regolith for as many uses as possible. We take one of two approaches:

1. Extracting resources out of the regolith, usually with chemical processes
2. Using the regolith as a raw material for building structures



In Situ Resource Utilization (ISRU)

- There is a great expense required to lift mass into orbit and beyond; how can we explore with less launched-mass?
- The solar system contains abundant resources; the atmosphere and soils of bodies. And sunlight!
- ISRU will mine these resources and convert them to mass saving commodities.
- We also look at converting wastes to useful commodities.
- If we want to **pioneer** in the solar system, we must use the resources that are in abundance!

Regolith & Atmosphere-Derived Resources

Potential sites for ISRU

- Moon
- Mars and it's moons
- Asteroids
- All other solar system bodies

CO_2 from the Mars Atmosphere

Water from the soil

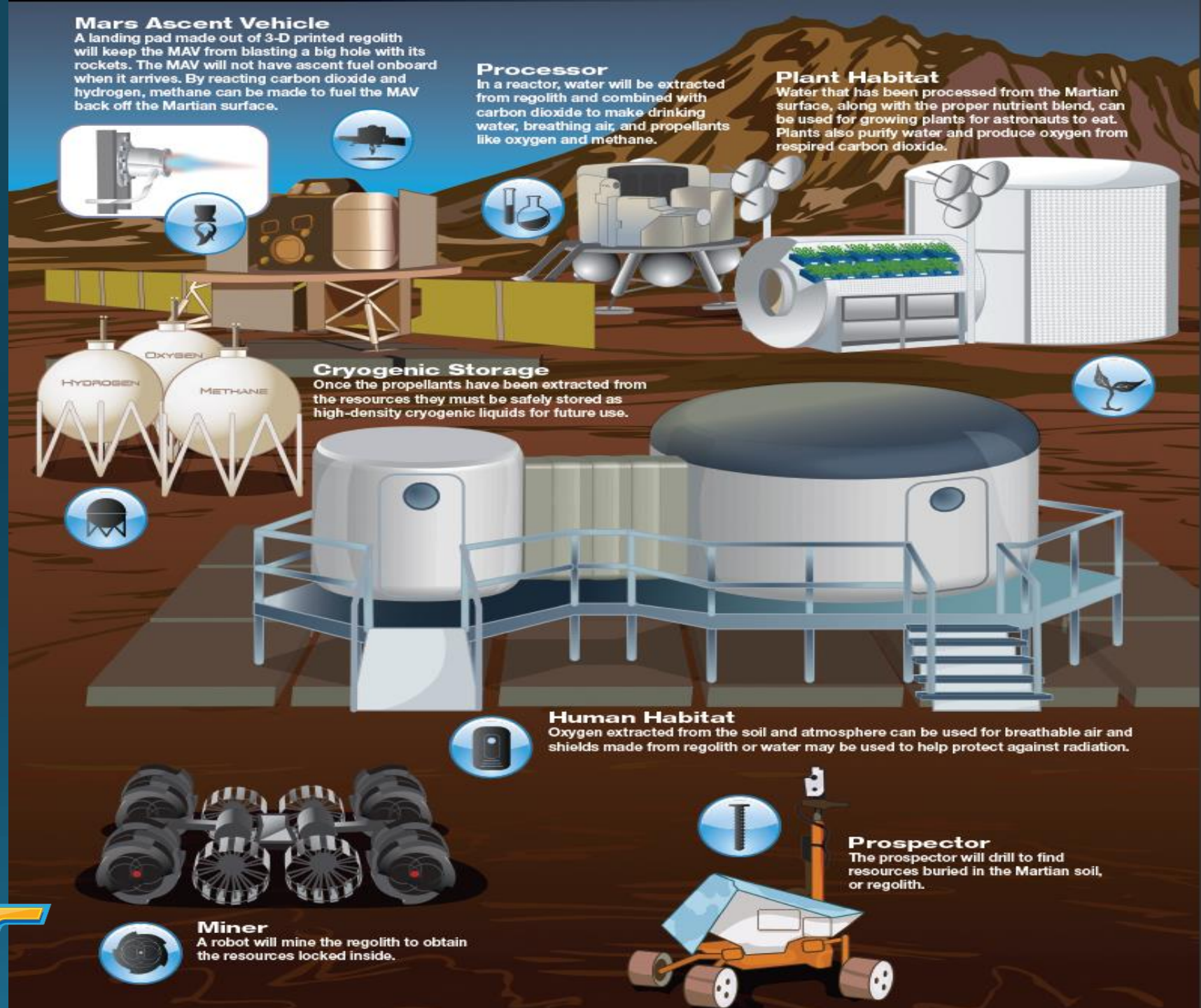
- Permafrost
- Hydrated minerals in soils
- Buried Glaciers

Regolith & Atmosphere-Derived Resources

The primary resources and products that we have studied:

- Oxygen from regolith
- Water from soil volatiles
- CO_2 from atmosphere (Mars)
- Construction materials based on regolith (radiation shielding, landing pads)
- Berms, trenches and other excavation structures
- Regolith for greenhouse soils
- Metals from regolith
- Plastics from soil volatiles
- Food and oxygen from plants

Developing the Tools to Meet the Challenges



DUST TO THRUST

MOON/MARS REGOLITH ROOM

A unique indoor facility featuring 120 tons of regolith simulant to support surface systems testing, especially in the area of robotic mining.

Martian Isolation Simulation

Trash to Gas

- Stabilization of all combustible waste, including human wastes
- Volume and mass reduction of stored waste

For a crew of four over one year, the waste can be used to:

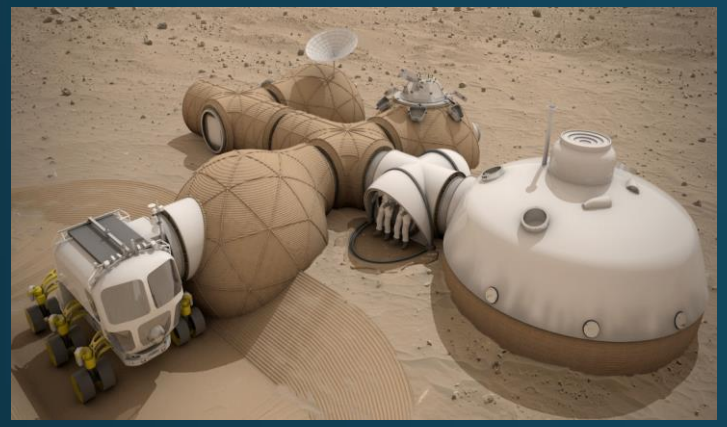
- Produce up 1500 kg of methane
- Produce up 300 kg of water

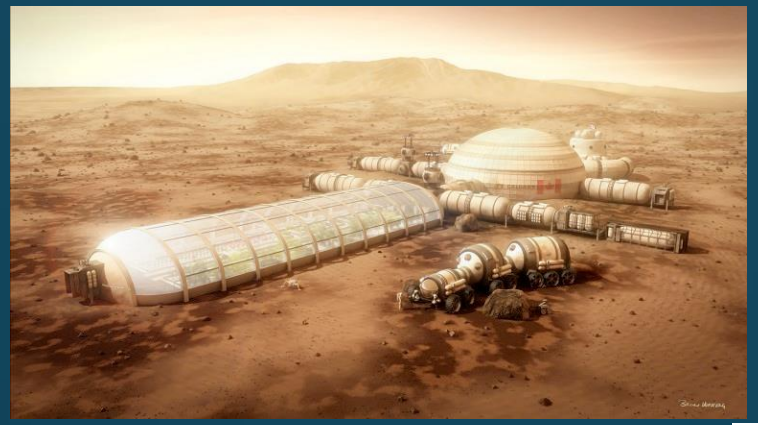
Waste Storage on ISS

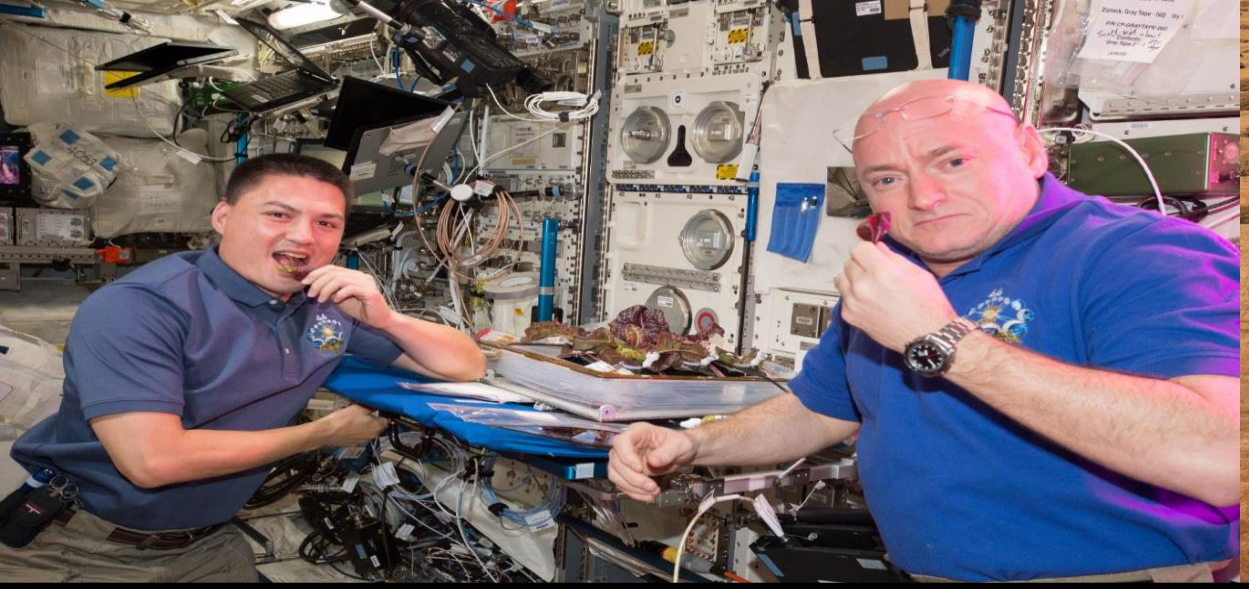
Food waste "football"

Oxygen
Water
Methane

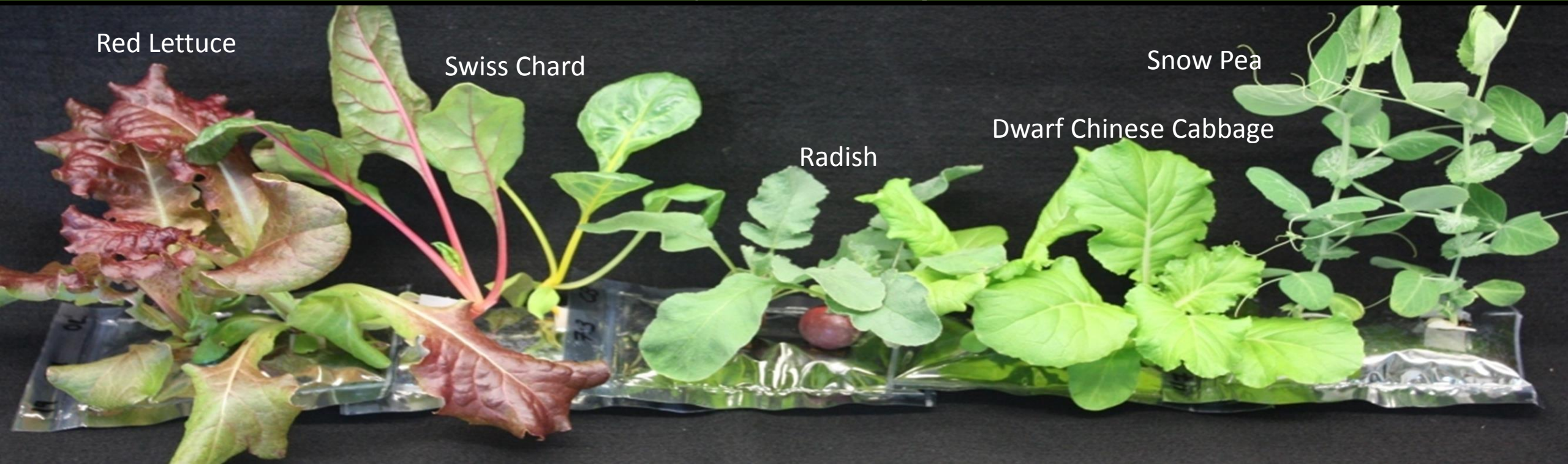
MARS - Advanced Habitats Shelters





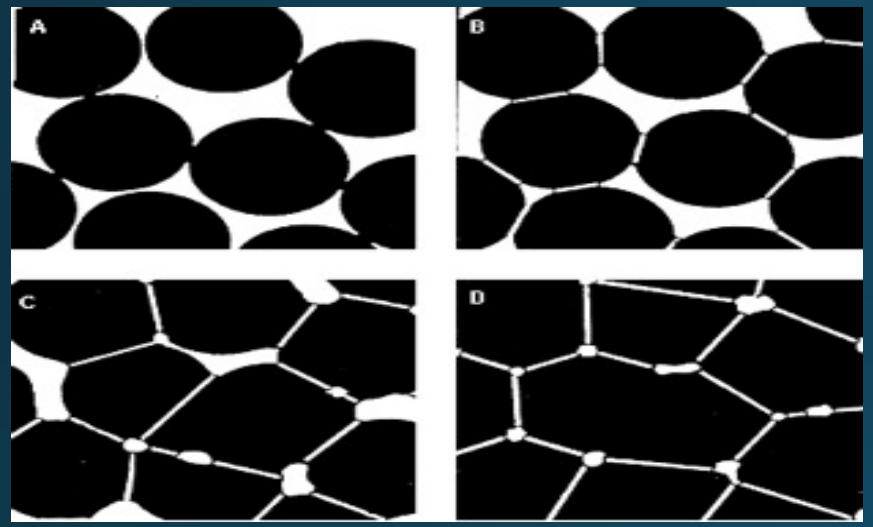


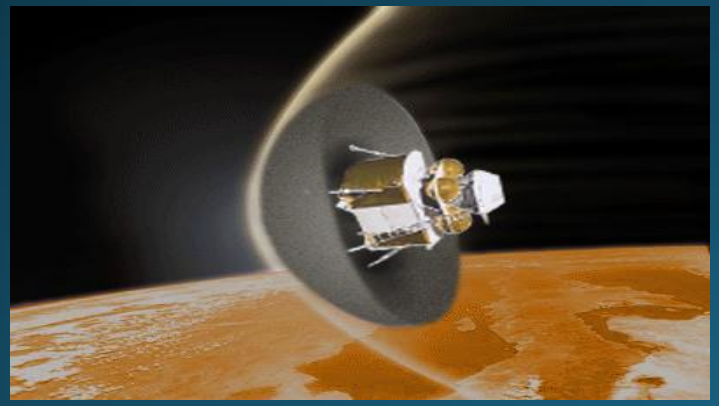
Growing Food in Space

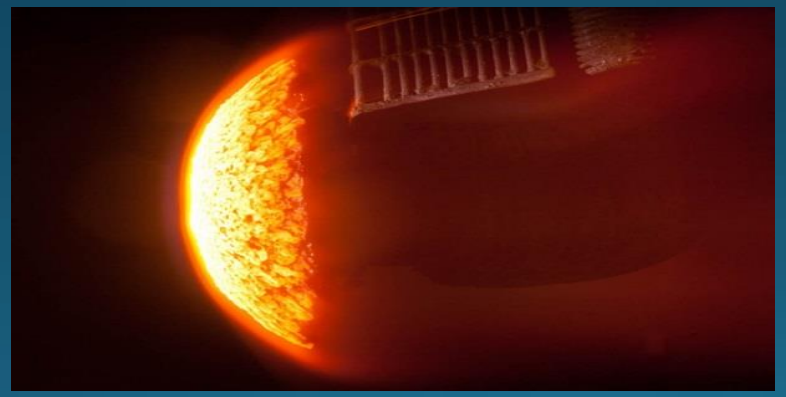


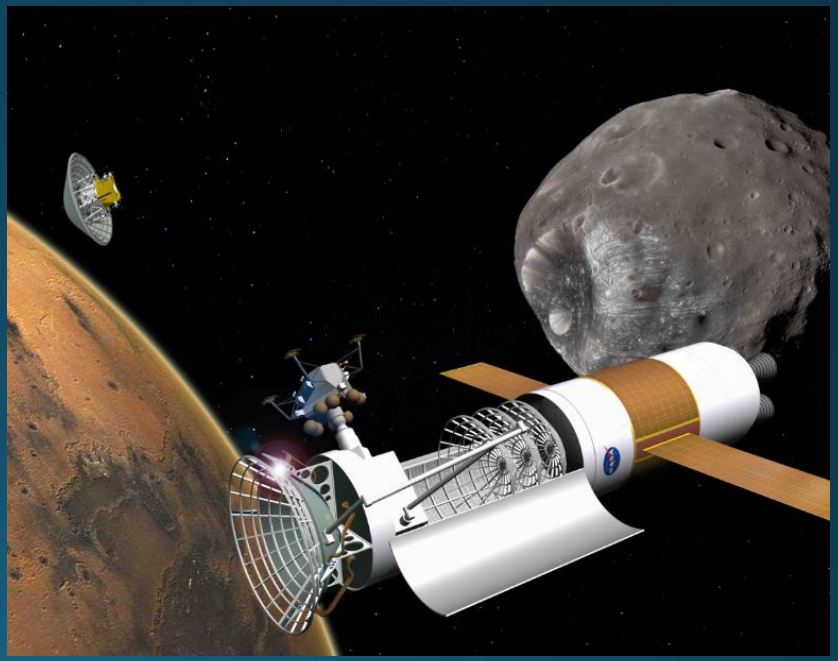
3-D Printing/Additive Manufacturing from Regolith-derived Materials

Heating the moon dirt to just-below-melting temperatures (1200-1500 °C) makes the dirt stick together. Robotic 3D printers can then build walls of a habitat, or launch pads, paved roads etc.

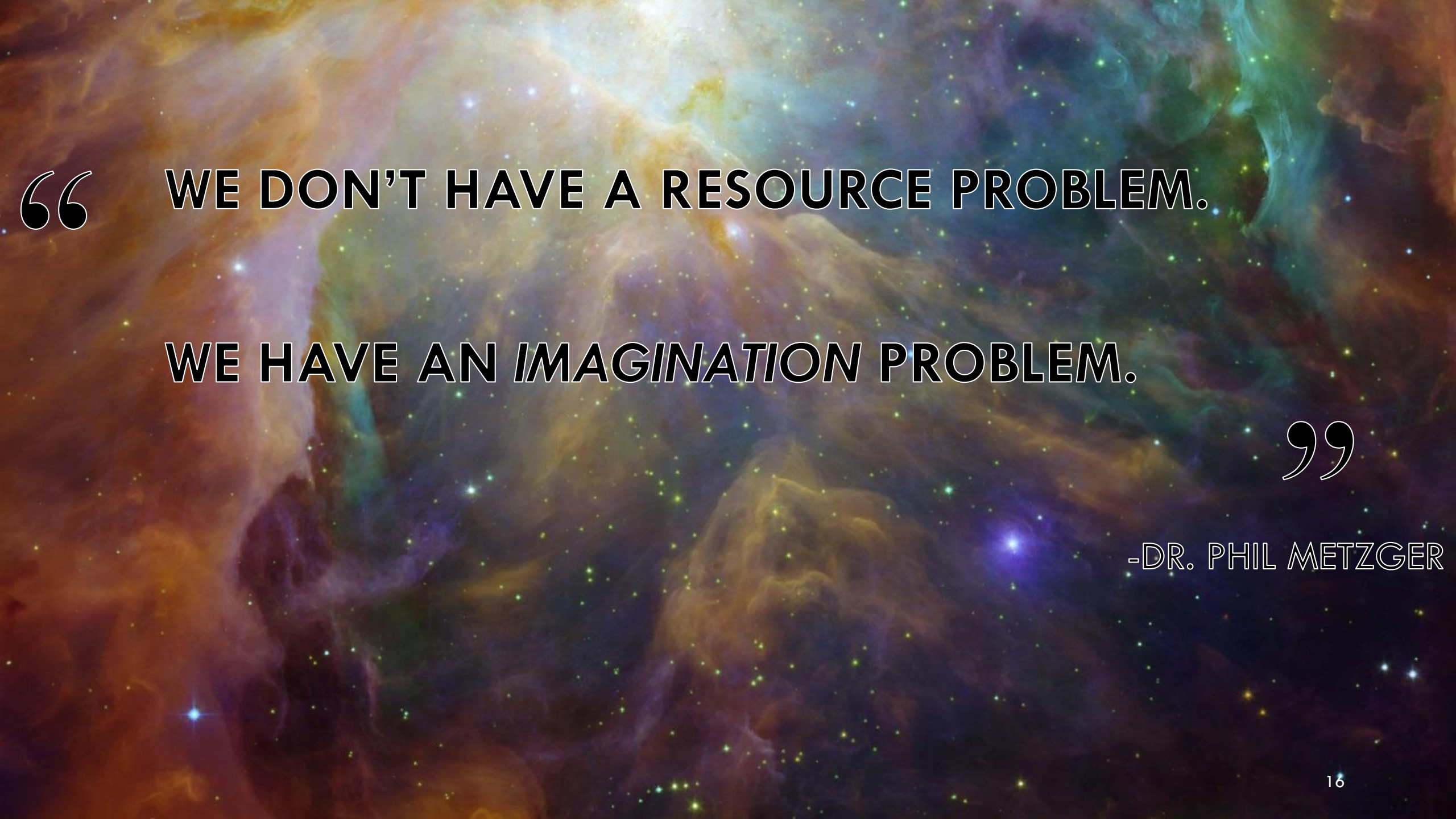








Regolith-derived heat shield sample undergoing flame testing at ARC; regolith samples post-test; artist concept. Image Credit: NASA/KSC


“ WE DON’T HAVE A RESOURCE PROBLEM.
WE HAVE AN *IMAGINATION* PROBLEM. ”
-DR. PHIL METZGER

Questions?